IEA Bioenergy

Country report The Netherlands

Gasification of biomass and waste

Berend Vreugdenhil (ECN.TNO)

OUTLINE

- Industry
  - ESKA
  - BEN
  - Gasunie
  - Torrgas
- R&D
  - CONVERGE
  - AMBITION
  - BECOOL
  - Black Birds

INDUSTRY

RWE AMER POWER STATION – NO UPDATE

- Gasifier connected to a 600 MW_e coal fired power station
- 85 MW_{th} CFB gasifier based on Lurgi technology
- Operation was possible due to subsidy

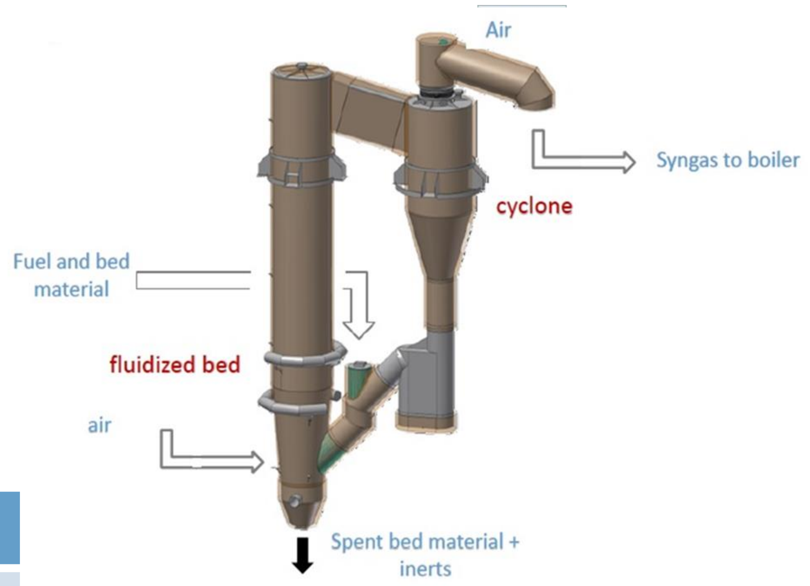
- Currently the gasifier is off-line
- RWE is upgrading the site to 100% sustainable

The Amer-9 coal-fired power station with the waste wood

ESKA PAPER REJECT GASIFICATION

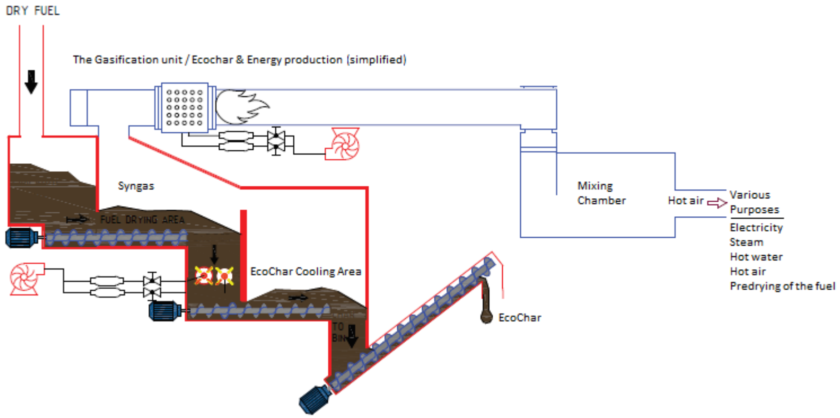
- CFB technology supplied by Leroux & Lotz (TPS technology)
- 10 - 13 MWth input CFB gasifier, depending on LHV rejects
- Boiler produces 5 – 16 ton/h steam (196°C, 13,6 barg)
- Fully automatic operation
- Build in 2016, in operation since Oct-2016

Year	Uptime[h]	RDF [h]	Energy [GJ]
2017	5892	4335	156.292
2018	6402	5255	170.740
Oct-2019	5181	4261	145.188



MAVITEC GREEN ENERGY – NO UPDATE

- Down draft fixed bed gasifier is the heart of the process.
- Products are a combustible gas and EcoChar
- Modular system




Turkey manure gasifier

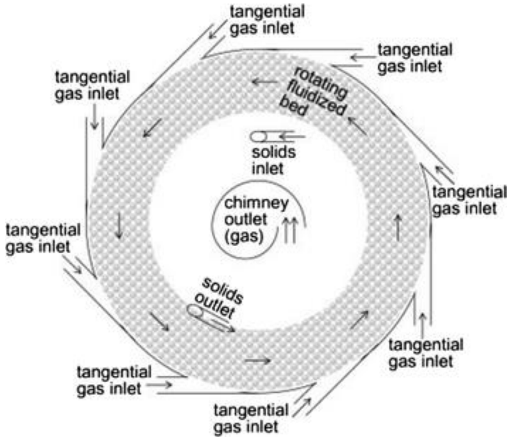

Poultry gasifier

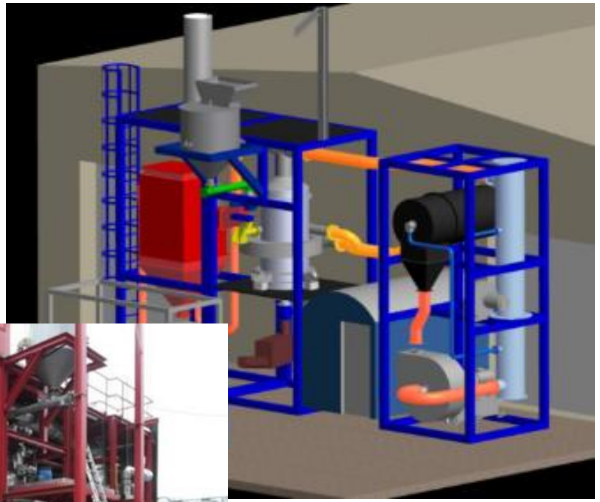

Digestate (cow manure) gasifier


Swine manure gasifier

SYNVALOR (START UP PHASE) – NO UPDATE

- Multi Stage Vortex gasifier
- Goal is to produce low tar gas from difficult feedstocks
- Currently starting up a CHP unit at a Gerbera grower in Mijdrecht





de Wilde J, de Broqueville A (2007) Rotating fluidized beds in static geometry: experimental proof of concept. AIChE J 53:793–810

BIO ENERGY NETHERLANDS (START UP PHASE)

- Based on Zero Point Clean Tech
- Fixed bed down draft technology
- 8 MW heat production
- 2 MW power production
- Started construction Nov-2017

- Future plans include
  - Hydrogen production
  - Carbon utilization as biochar
  - CO_2 utilization

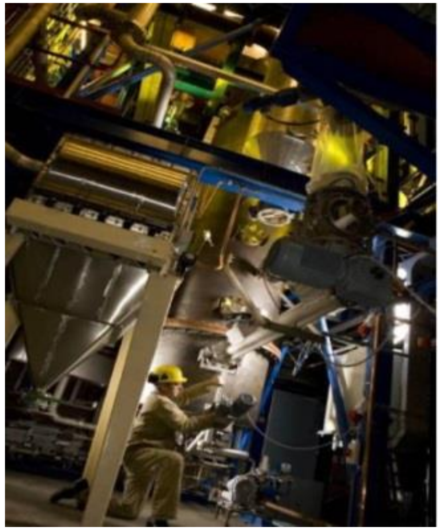
ZeroPoint (Ireland)

Artist impression of BEN (Amsterdam)

GASUNIE SUPPORTED INITIATIVES

AMBIGO Green Gas

- 4 MW_{th} indirect gasification
- Demolition wood
- T ~ 850°C
- P ~ 1 bar



Cancelled

SCW Green Gas

- 2 MW_{th} super critical
- Wet biomass
- T > 375°C
- P > 221 bar

Commissioning phase

Torrgas Green Gas

- 0,7 MW_{th} direct gasification
- Torrefied biomass
- T > 1050°C
- P ~ 1 bar

See next slides

DEVELOPMENT WASTE TO METHANOL – NO UPDATE

Waste to Methanol project Rotterdam

- Based on Enerkem technology
- O_2 blown BFB gasifier
- 360 kton/a waste → 220 kton/a MeOH

Partners

-Port of Rotterdam

-Enerkem

-Nouryon

-Air Liquide

-Shell

Photo: Enerkem plant in Canada

TORRGAS

- Modular setup of syngas production
- Operated on torrefied biomass to simplify feeding
- First step is fast pyrolysis
- Second step is gasification using oxygen
- Products are syngas and biochar

- Syngas gas be used for methane, methanol and other chemicals

Catalytic grade syngas and engineered carbon from torrefied biomass

Dilemmas that need to be resolved for the creation of a sustainable biobased economy: **gasification dilemmas**

Technology dilemmas:

- Low Temperature(<700 C): **tars**, no slagging.
- High temperature (>1000 C): **slag**, little or no tars.
- Mid temperature (700-1000 C): **slagging and tars.**
- **Variability** of feedstock is a huge challenge for an 8000 hours/year, continuous and stable operation.
- **Moisture** in biomass lowers the conversion efficiency.
- **Scalability** is limited by the low energy density and moisture of biomass.

Solution: mitigate dilemmas

Torrgas mitigates fundamental risks which are often encountered in traditional biomass gasification:

1. Feed continuity: torrgas delivers a stable and efficient operation by applying homogeneous, high energy density, moisture free torrefied biomass.
2. Slagging: which has significant negative impact on both the Capex and Opex of a gasifier: torrgas technology circumvents slagging by immobilizing char.
3. Expensive tar cleaning: this is avoided by complete cracking of tars in the second step gasification. Tar formation in pyrolysis is reduced by almost 100%.
4. Scalability: torrefied biomass and correct system integration allow scaling to 50-100 MW_{th} in skid mounted reactor solutions

torrgas

Current status developments Torrgas

Torrgas key focus is on the complete biobased value chain demonstration of 25 MW in Delfzijl(Nl) to be expanded to 500 MW. A 50 MW green hydrogen project in front end engineering phase.

- 1 MW demo at DNV-GL continuous tar&nitrogen free syngas production(TRL7):
  a. >82% thermal efficiency(char and syngas) due to moisture free high energy density(22 GJ/mt) feed.
  b. CO:H2 about 1:1

- Final Investment Decision Gasunie for € 50 million, 25 MW SNG project in Delfzijl.

- SDE+ feed in tariff subsidy granted (€92 million for 12 years @ €86 per MWh for SNG).

- Feedstock is torrefied recycled wood

- Proof of engineered carbon spec (92% Carbon, 450 m^2/g+)

- SNG productions creates basis for platform chemicals production. It proofs the synthetic step.

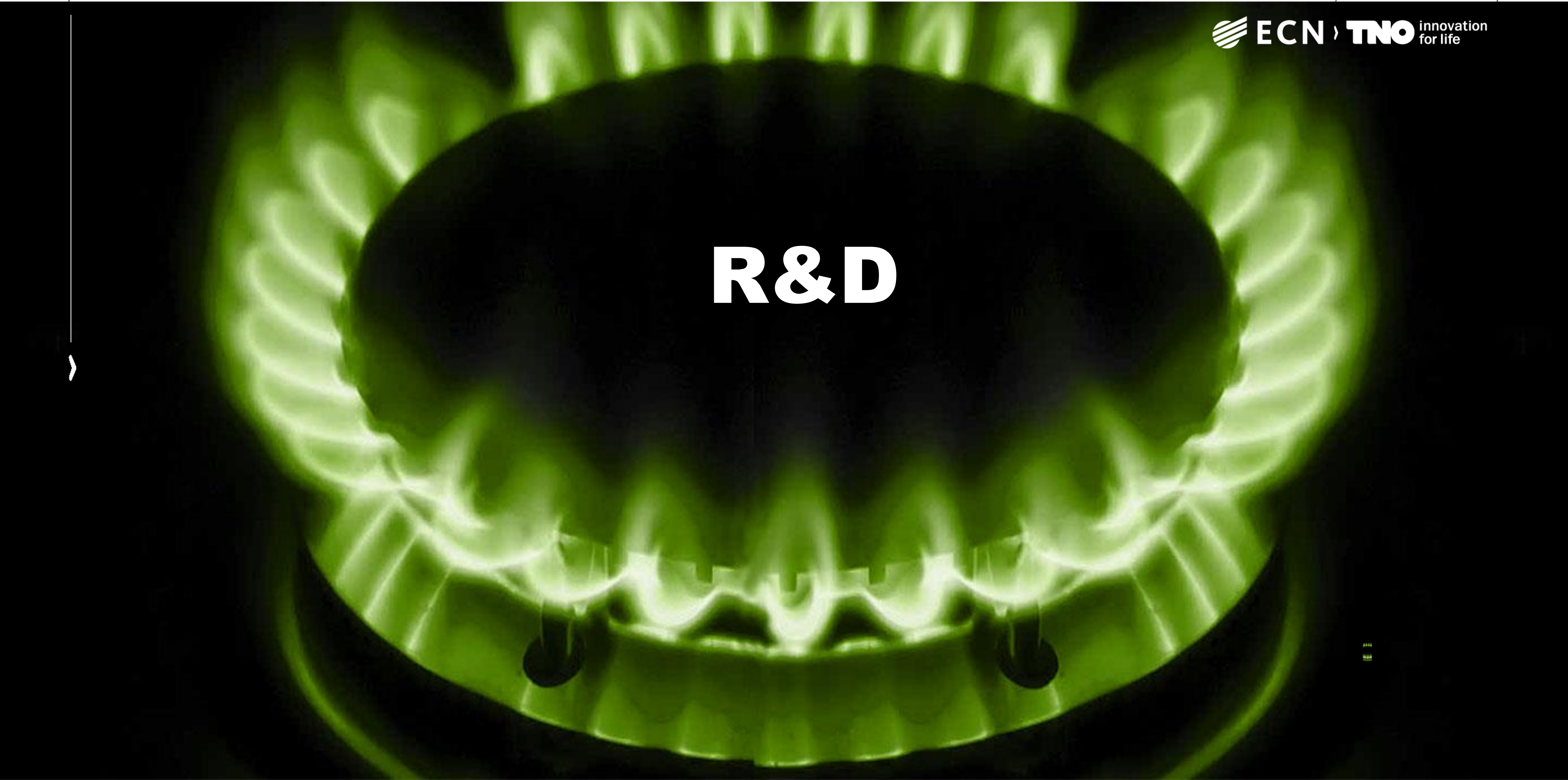
torrgas

Key characteristics of Torrgas solution

- Modular
- High pressure operation possible
- Torrefied standardized pellets from a wide variety of feedstocks(wood aswell herbaceous)
- High efficiency(no moisture in feed)
- Tar & nitrogen free catalytic grade syngas
- Scalable to 100 MWth per reactor

torrgas

R&D



POLITECNICO MILANO 1863

Group of Energy COnversion Systems

CONVERGE

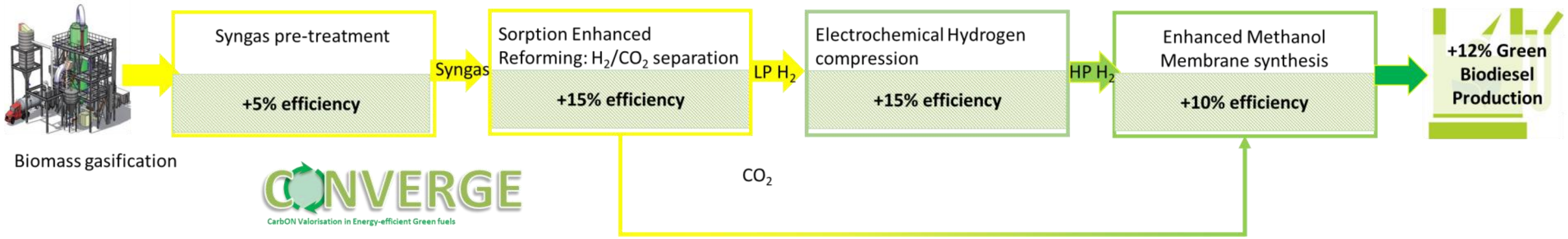
CarbON Valorisation in Energy-efficient Green fuels

The CONVERGE project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 818135

PROJECT OBJECTIVES

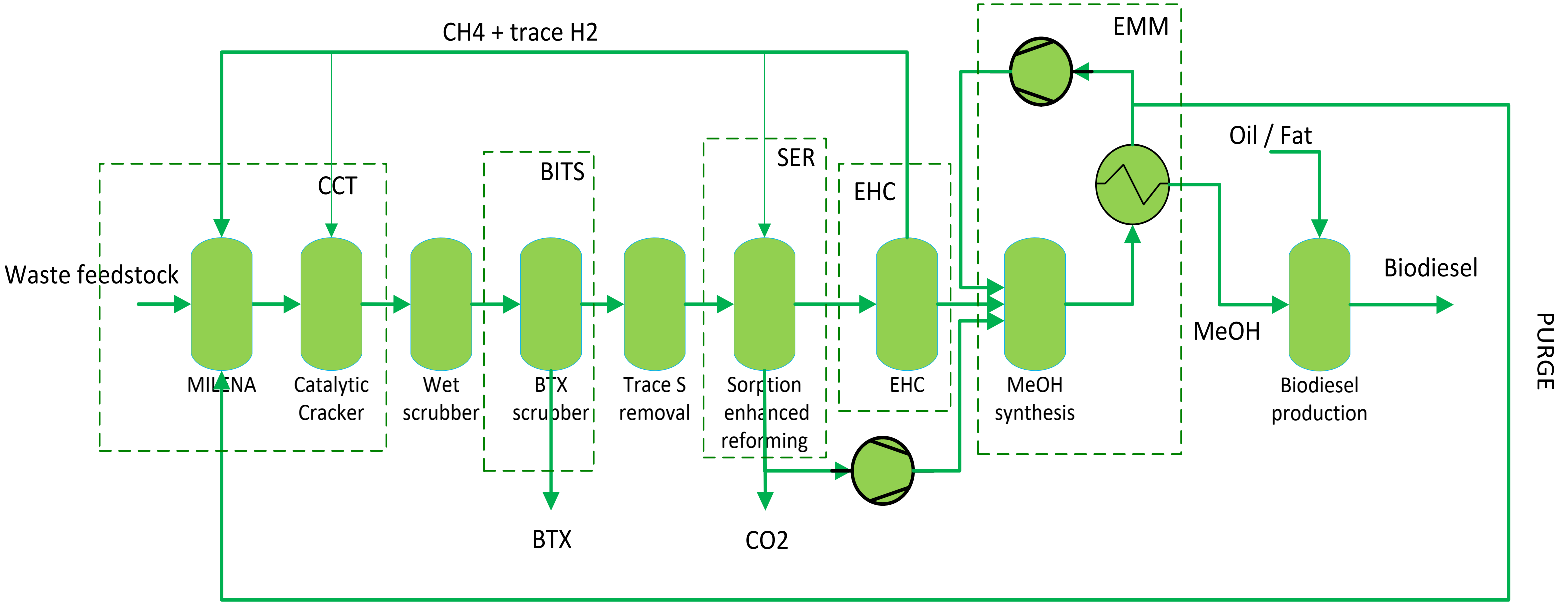
The **CONVERGE project will validate an innovative process** which will **increase the biodiesel production by 12%** per secondary biomass unit used and **reduce the CAPEX by 10%**

The **CONVERGE technologies will be validated** for more than **2000 cumulated hours** taking these from the discovery stage (TRL3) to development stage (TRL5).



The project started 12 months ago on November 1st 2018

PROCESS



- CCT: Catalytic cracking of tars from an indirectly heated gasifier to below green C_8
- BITS: Recovery of refinery products including aromatics for green C_6-C_8 fraction (BTX)
- SER: Sorption-Enhanced Reforming of C_1-C_6 for excess-carbon removal, and H_2 production
- EHC: Highly efficient electrochemical compression of green H_2 with by-product fuel
- EMM: Enhanced Methanol Membrane to ensure efficient green biodiesel production

ACKNOWLEDGMENTS

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ADVANCED BIOFUEL PRODUCTION WITH ENERGY SYSTEM INTEGRATION

Connecting lignin gasification with gas fermentation

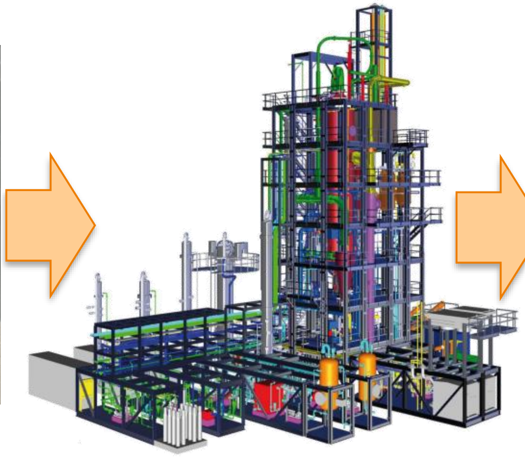
Eleni Liakakou[1], Alba Infantes[2], Anke Neumann[2], Berend Vreugdenhil[1]

[1]ECN part of TNO, Biomass and Energy Efficiency unit (The Netherlands)
[2]KIT, Technical Biology group (Germany)

Karlsruhe Institute of Technology

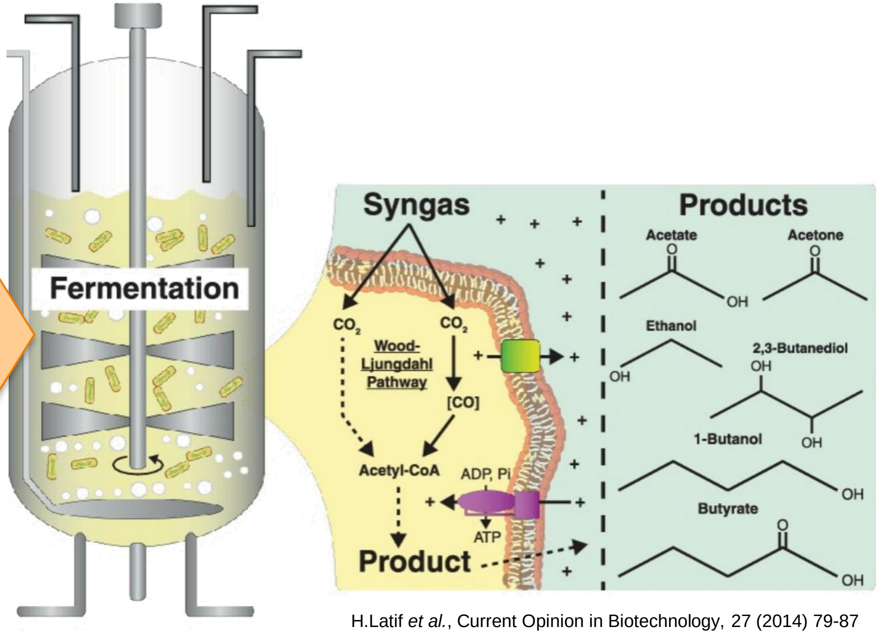
BACKGROUND INFORMATION

Lignin



Gasification

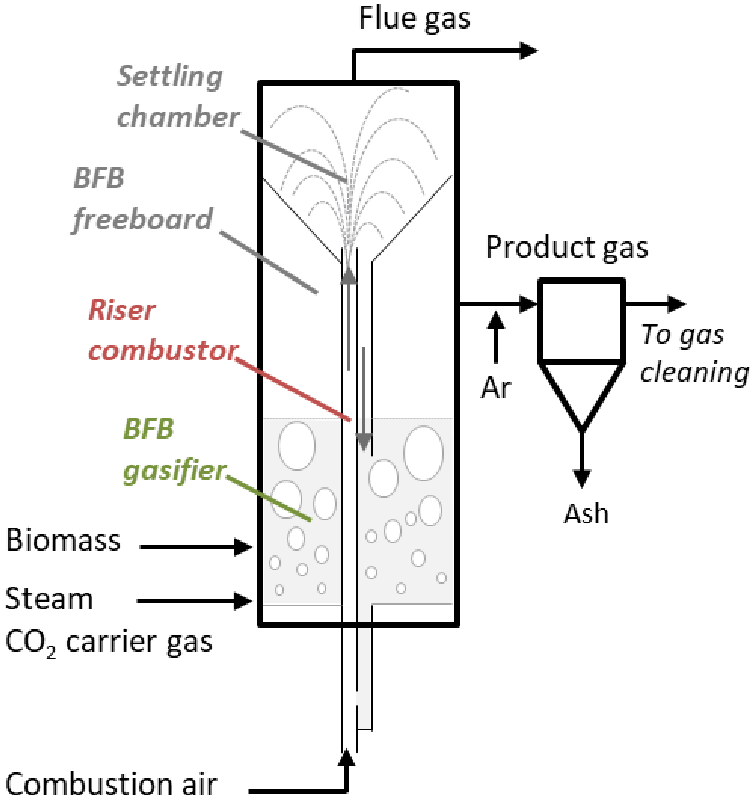
Gas cleaning



H.Latif *et al.*, Current Opinion in Biotechnology, 27 (2014) 79-87

- Our AMBITION: increase the value of bio-refinery residues by developing lignin derived energy products
- Challenge: gasification of this difficult feedstock with different properties than beech wood
- Gas cleaning to the fermentation requirements (low aromatics, unsaturated HCs, S-compounds, HCN, NH_3)
- Goal: coupling gasification with gas fermentation

INDIRECT GASIFICATION AT ECN>TNO



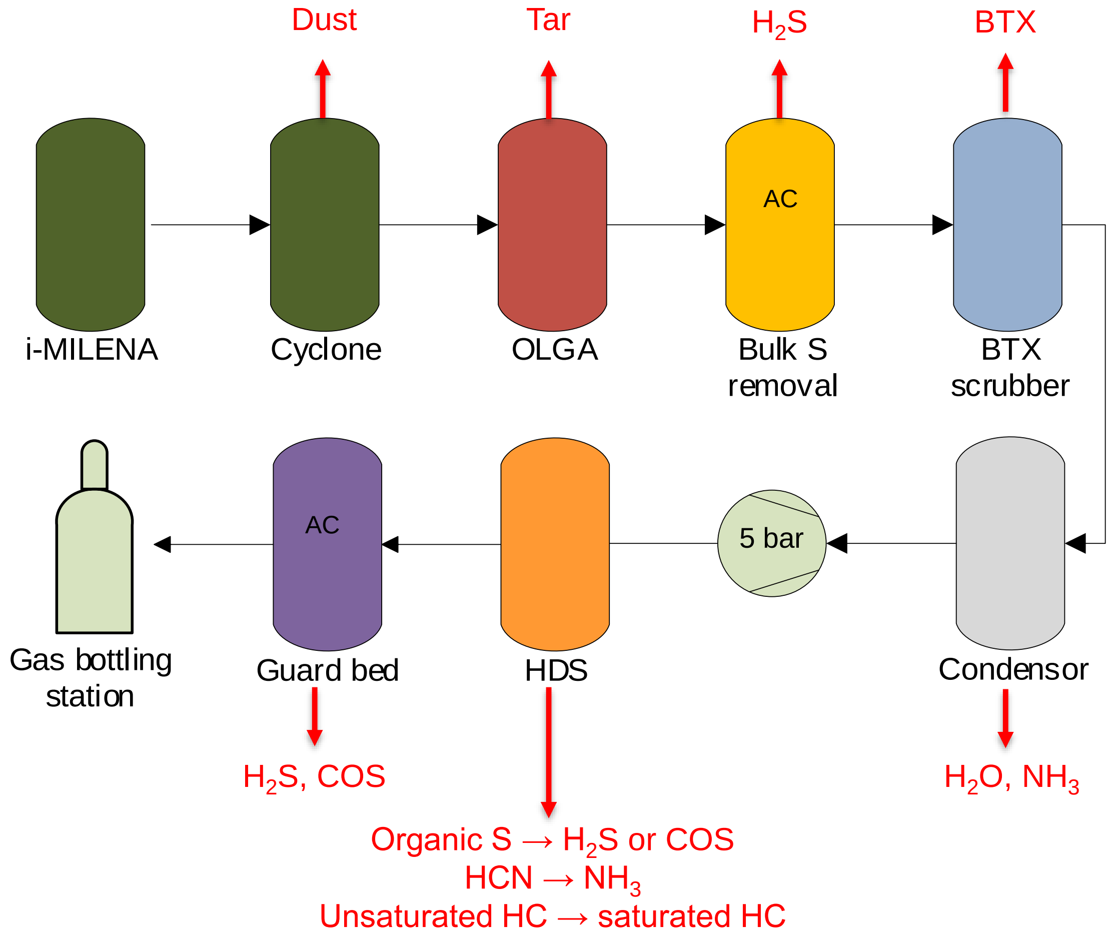
- Gasification and combustion in one reactor
- No N_2 dilution
- Complete C conversion

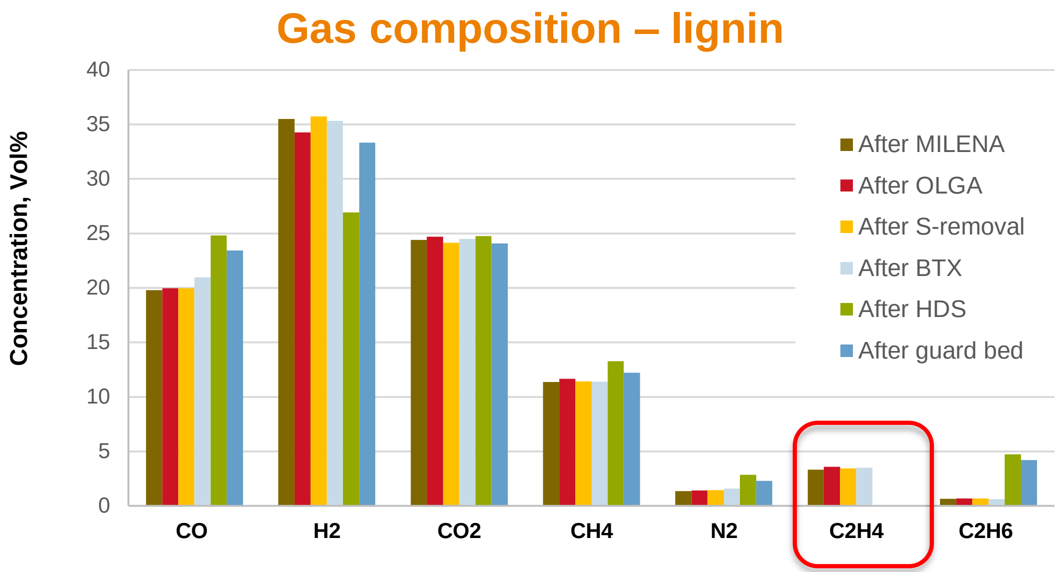
Gasification temperature:
Beech wood = 860°C
Lignin = 760°C

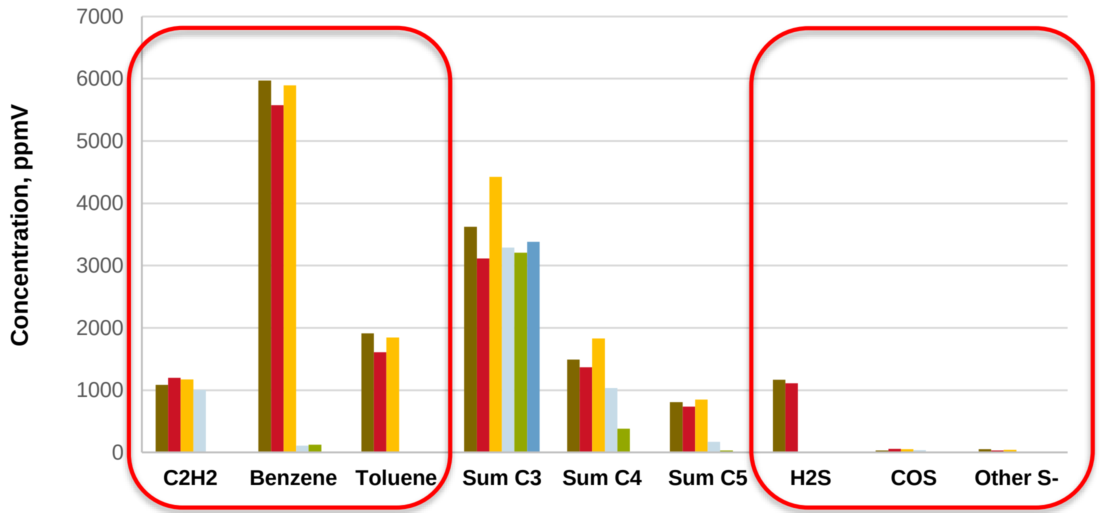
Bed material: fresh Austrian Olivine
Fluidization agent: steam

Gas analysis: online gas analyzers and μ-GC, offline GC-FID for HCs and GC-PFD for S-compounds

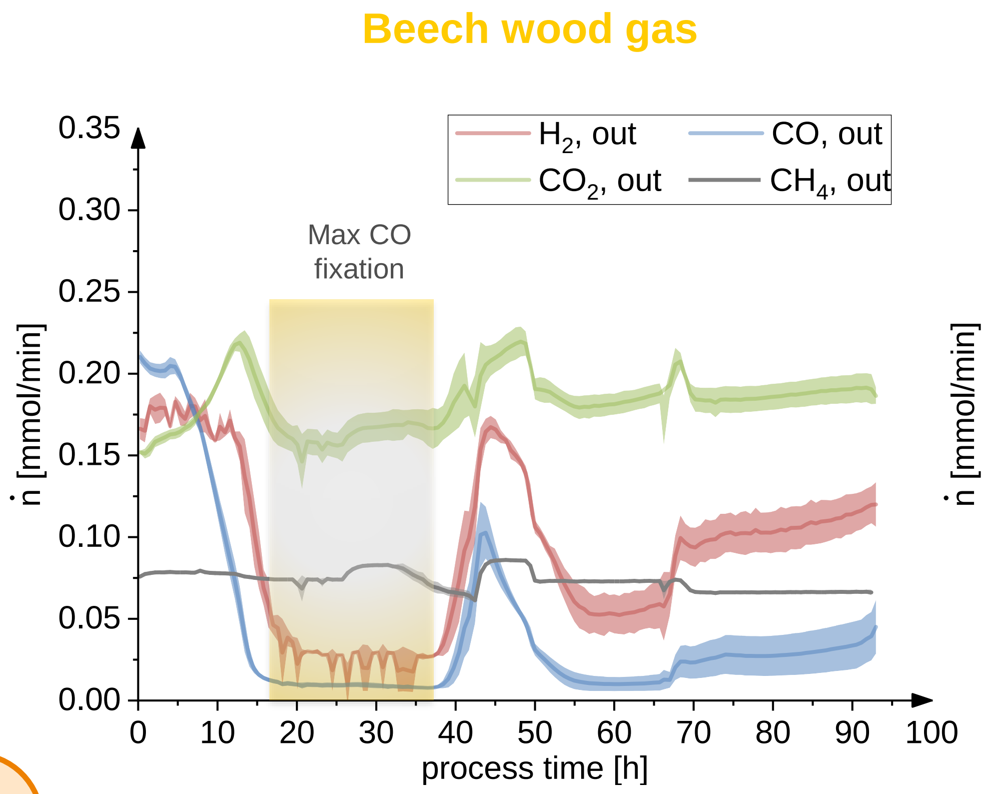
PRODUCT GAS CLEANING

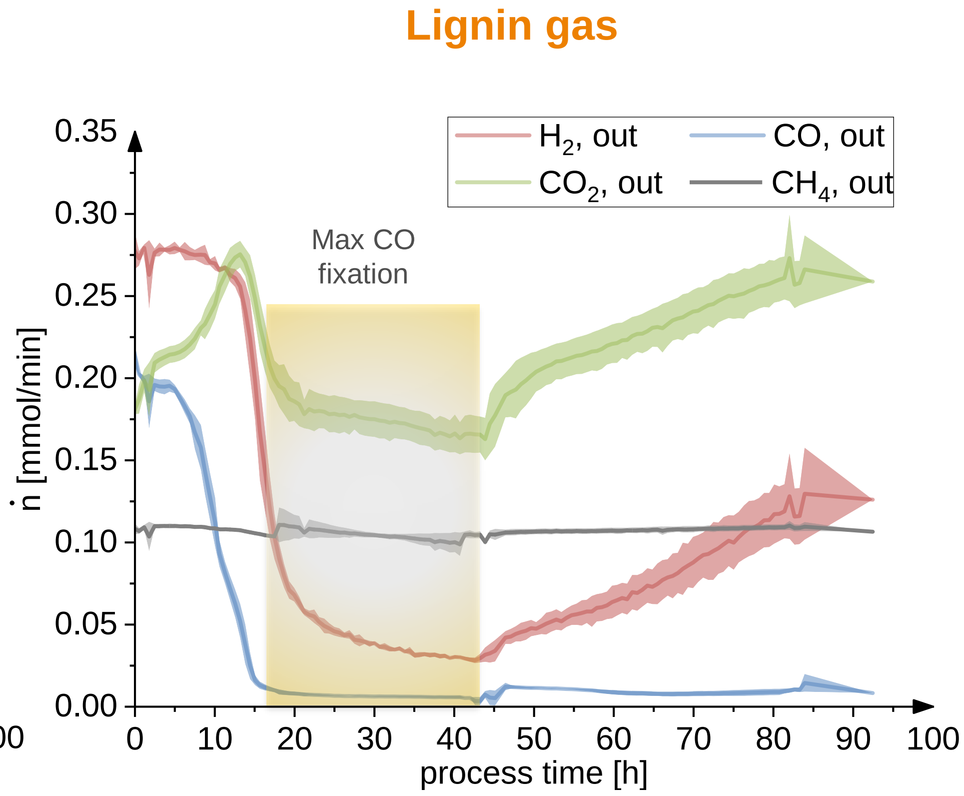






SUCCESSFUL GAS FERMENTATION AT KIT





T_{ferm} = 37°C

pH_{ferm} = 5.9

C. ljungdahlii DSM 13528

On-line gas analysis

Process time: ~95h

Same inlet $CO+CO_2$ molar flow

- Completely fermentable gas
- Almost complete CO consumption: 91% for beech wood, 95% for lignin (during the maximum interval)
- Methane acted as inert

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THANK YOU FOR LISTENING

This project has received funding from the European Union’s Horizon 2020 Research and Innovation Programme under grant agreement number 731263

AMBITION

BECOOL

Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels

Building value chains for large scale FT production

28 may 2019

Evert Boymans, P. Abelha, B.J. Vreugdenhil

ECN › TNO innovation for life

M. Buffi, D. Chiaramonti

RE-CORD

This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under grant agreement No. 744821.

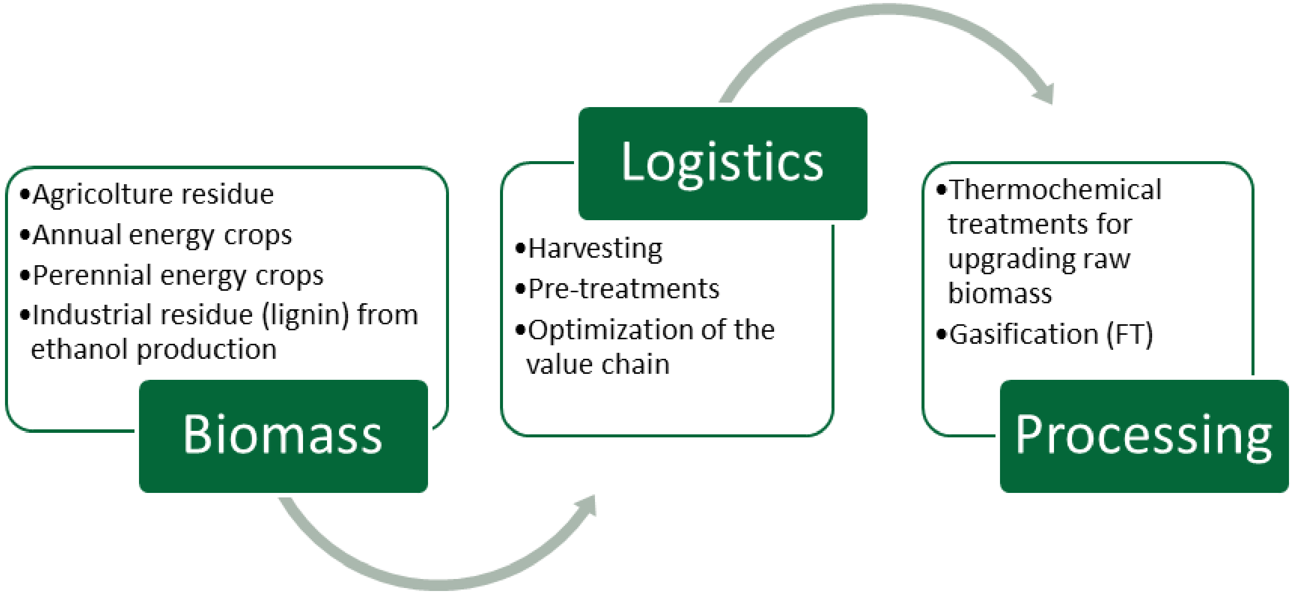
The BECOOL project

BECOOL is a research and innovation project to promote the cooperation between EU and Brazil in the development of advanced biofuels, from sustainable agricultural value chains, based on lignocellulosic biomass.

Horizon 2020

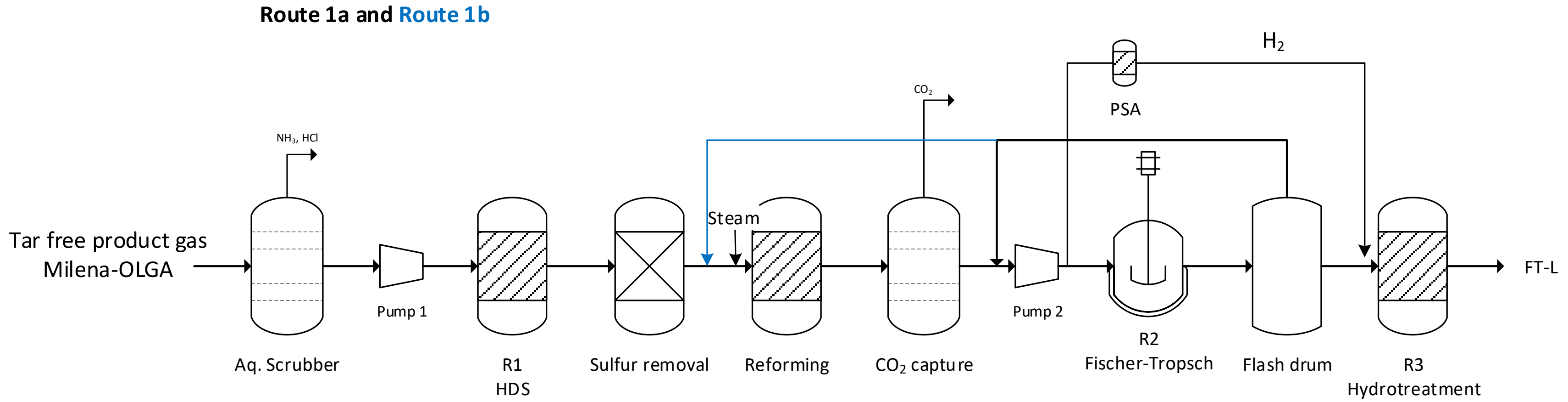
Objectives

- Developing and validating integrated technology packages
- Strengthen EU-Brazil cooperation



Task 3.2.3 Modeling progress

Aspenplus model results: Milena product gas cleaning/upgrading/FT synthesis
Input: Eucalyptus product gas (experimentally determined, tar free)



		Naphtha	Kerosene	Diesel	Chemical efficiency	Overall efficiency
Efficiency route 1a	[%]	12	28	13	53	48
Efficiency route 1b	[%]	12	26	12	50	45

Respectively 45 MW and 48 MW of (excess) steam at 125°C available

Recycle to Reformer results in lower efficiency due to increased reformer heat duty

Task 3.2.1/3.2.3 Solid biomass gasification and gas cleaning

The gasification of Fiber Sorghum

Goal: demonstrate gasification + gas cleaning (upto reformer)

As received chipped Fiber Sorghum:
- Fibrous material
- Low bulk density (~100 g/L)

Pretreatment:

Biomass Sorghum - As received

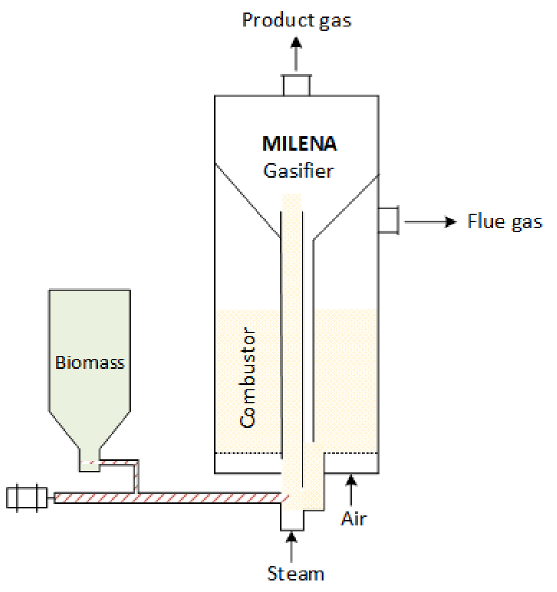
Grinding + pelletization

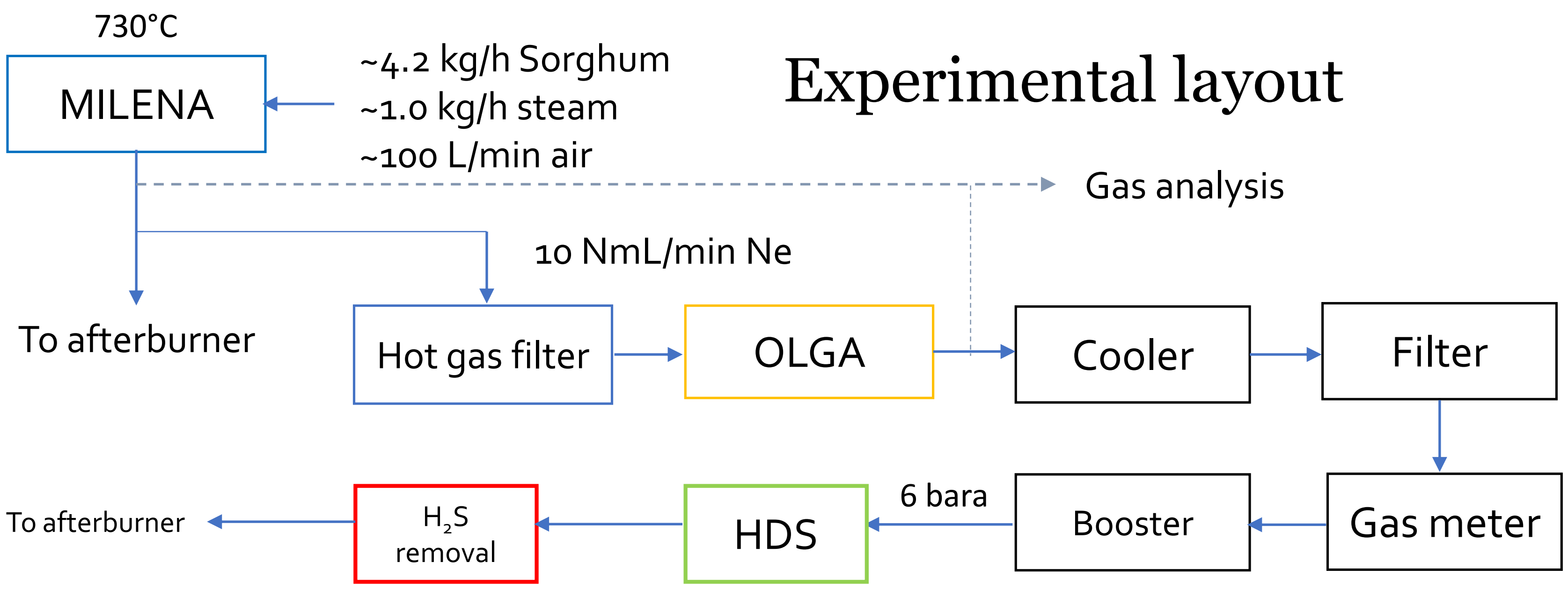
6x18.5 mm pellets

Grinding

<4 mm Sorghum Gasification feedstock

Sorghum gasification and gas cleaning





1- day experiment
Gasification (MILENA) followed by tar removal (OLGA) and sulphur removal (HDS).

Challenge: high sulphur content in feedstock and product gas
HDS catalyst: commercially available supported CoMo pellets
H_2S removal: ZnO pellets

Sorghum gasification and gas cleaning

Gas composition:

Gas component	Unit	MIL-OLGA	HDS
CO	[Vol%]	34.3	35.2
H_2	[Vol%]	11.3	5.7
CO_2	[Vol%]	23.3	27.7
CH_4	[Vol%]	14.5	16.3
C_2H_4	[Vol%]	4.6	0.05
H_2S	[Vol%]	982	0.71
Thiophene	[ppmV]	7	1.34
Methylmercaptane	[ppmV]	107	0.06

Very high sulfur concentration in product gas

- 99.9% H_2S removal; for FT synthesis ppb levels required; extra guard or amine scrubber
- 81% thiophene conversion in HDS is not sufficient
- Reason: High S concentration and low H2 concentration (6-11% vs normally 20-25%)
- Solution: more H2 (WGS?), higher operation P and/or T

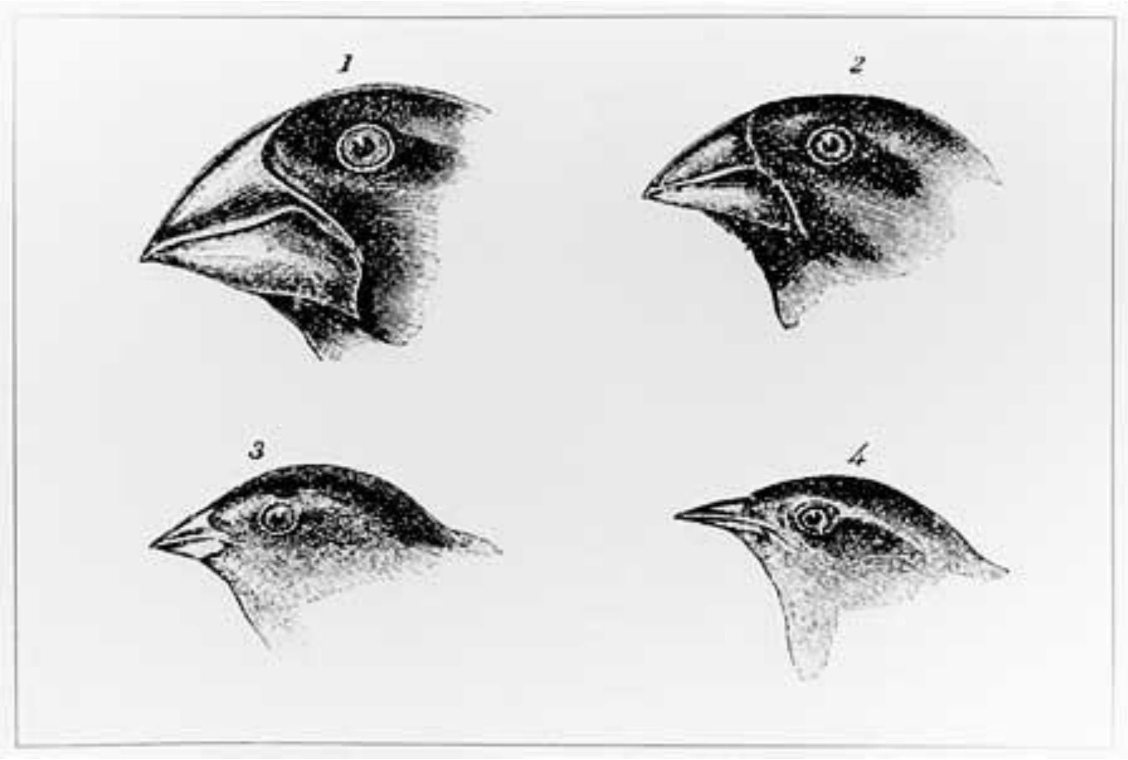
Eucalyptus gasification in same line-up led to full thiophene and mercaptane conversion in HDS.

- Reason: Less S-components, higher H2 concentration (17%), less ethylene (1.6%)
- Pretreatment of Eucalyptus only involved grinding (no pelletization, 0-2 mm particles, 220 g/L)

BLACK BIRDS

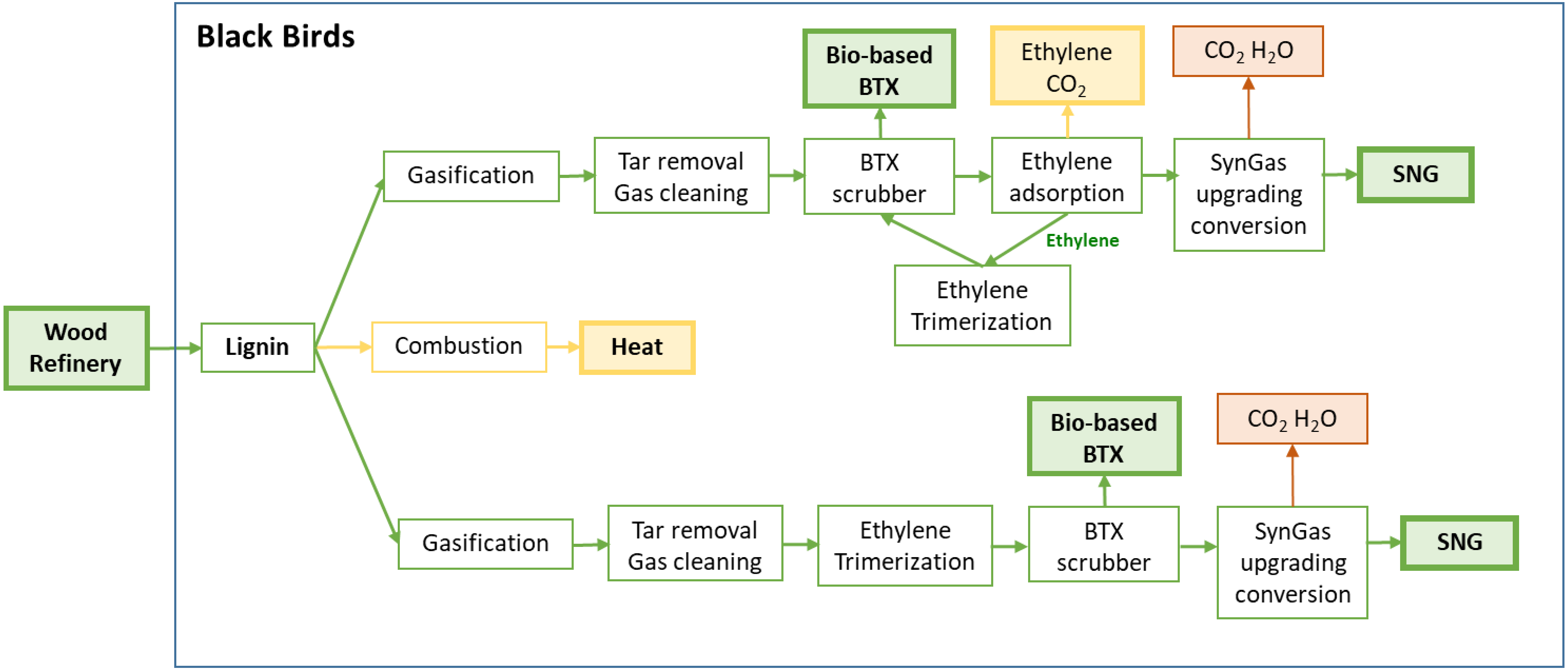
Combined thermochemical and catalytic processing adapted for the production of high-value products and energy from lignin

TEBE117010

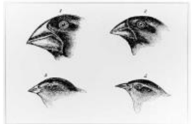


BLACK BIRDS SCHEME

- Production of high value products and energy from lignin

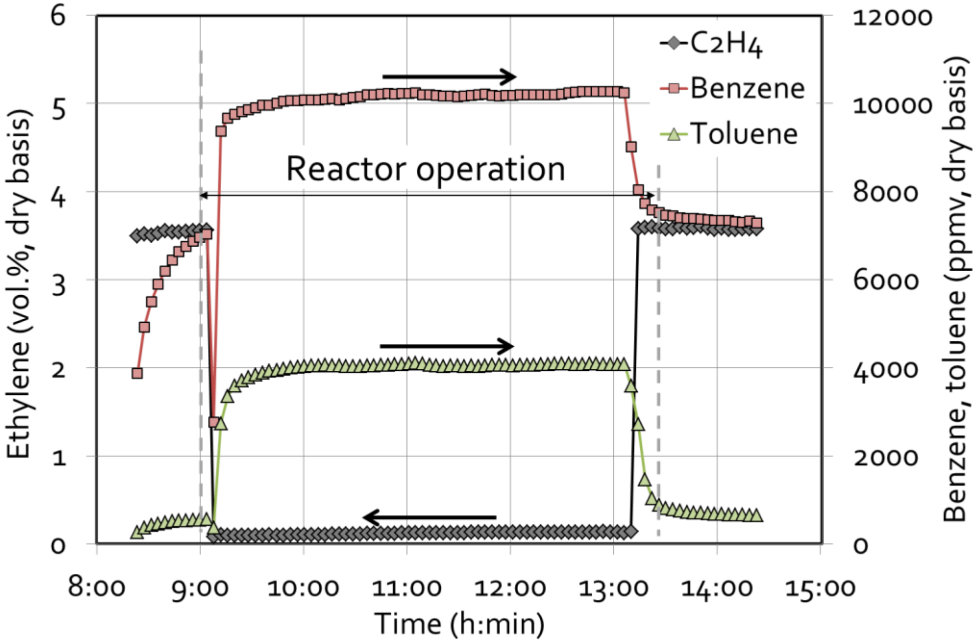


HIGHLIGHTS



Bio-BTX scrubber unit + automated product separation (1 Nm³/h feed)

> 98% BTX recovery from product gas



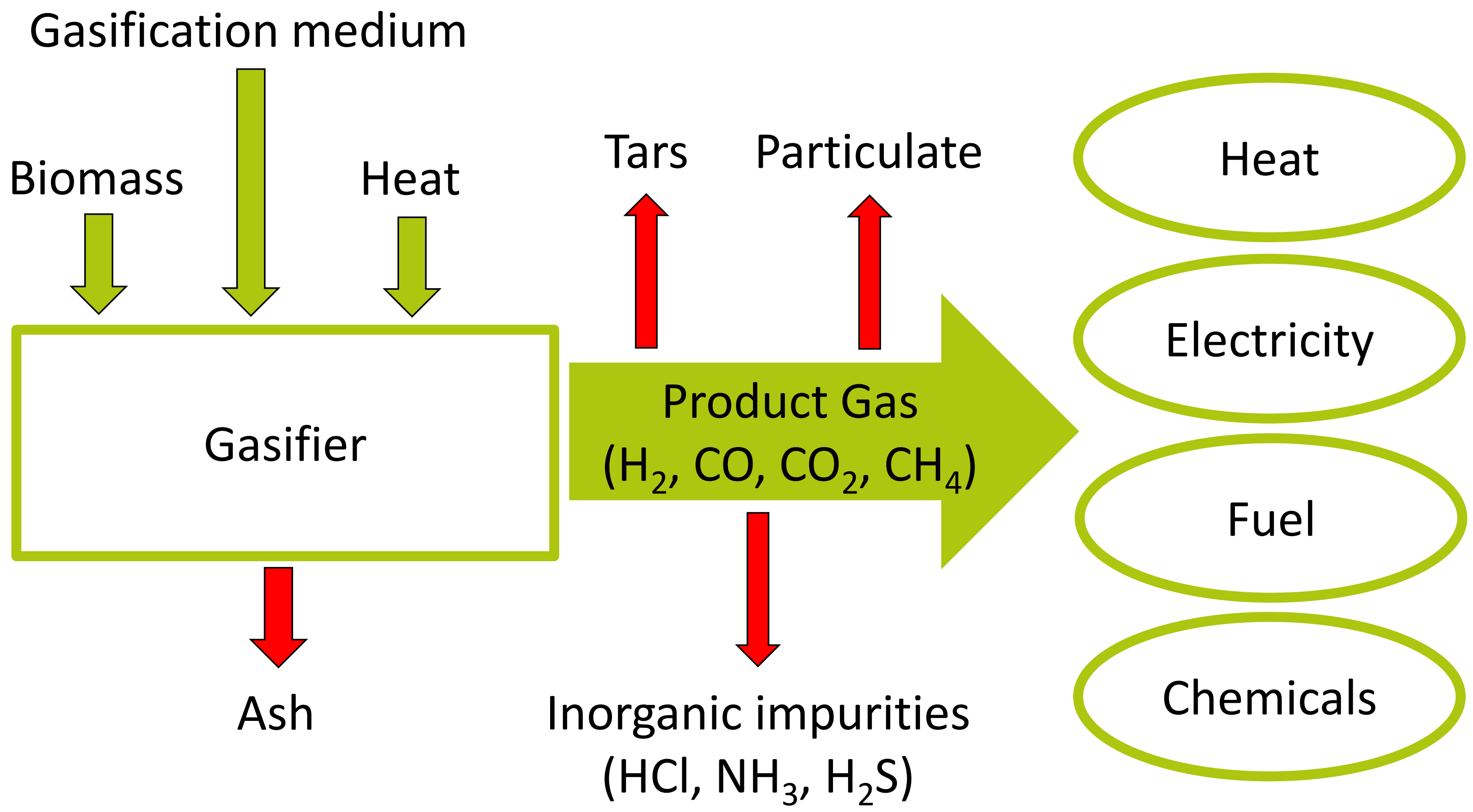
>97% ethylene conversion
X 1.4 increase in benzene content
X 8 increase in toluene content

Biomass Gasification in a Novel 50kW$_{th}$ Indirectly Heated Bubbling Fluidized Bed Steam Reformer: Preliminary Experimental Results and Process Modelling

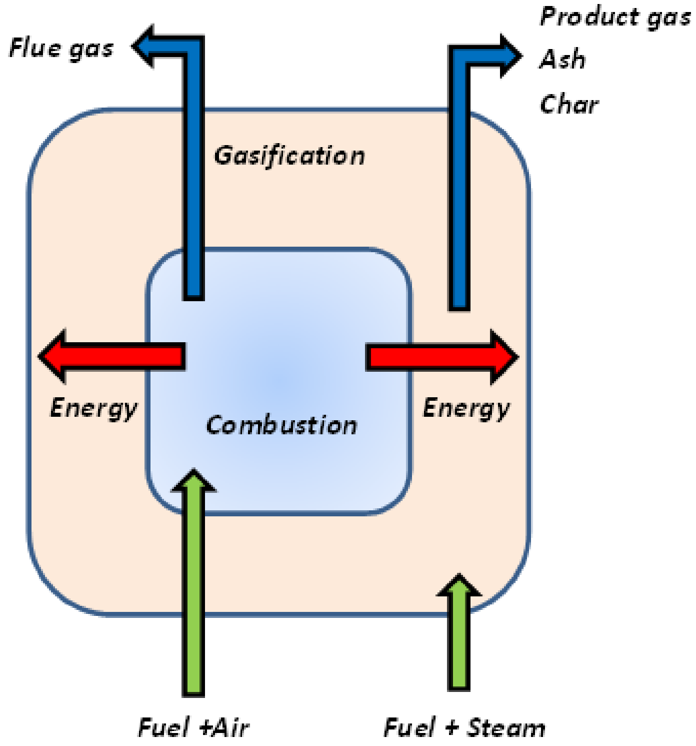
Collaboration project between
TU Delft and Petrogas-Gas Systems

PhD student: Mara Del Grosso
Project supervisor: Wiebren de Jong

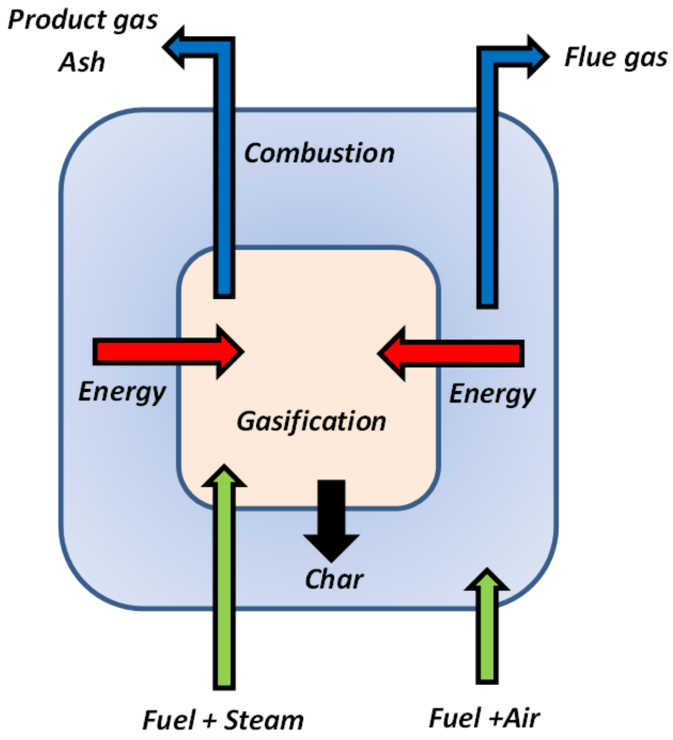
Project overview: Gasification Technology



Project overview: Comparison of working principles



IHBFBSR

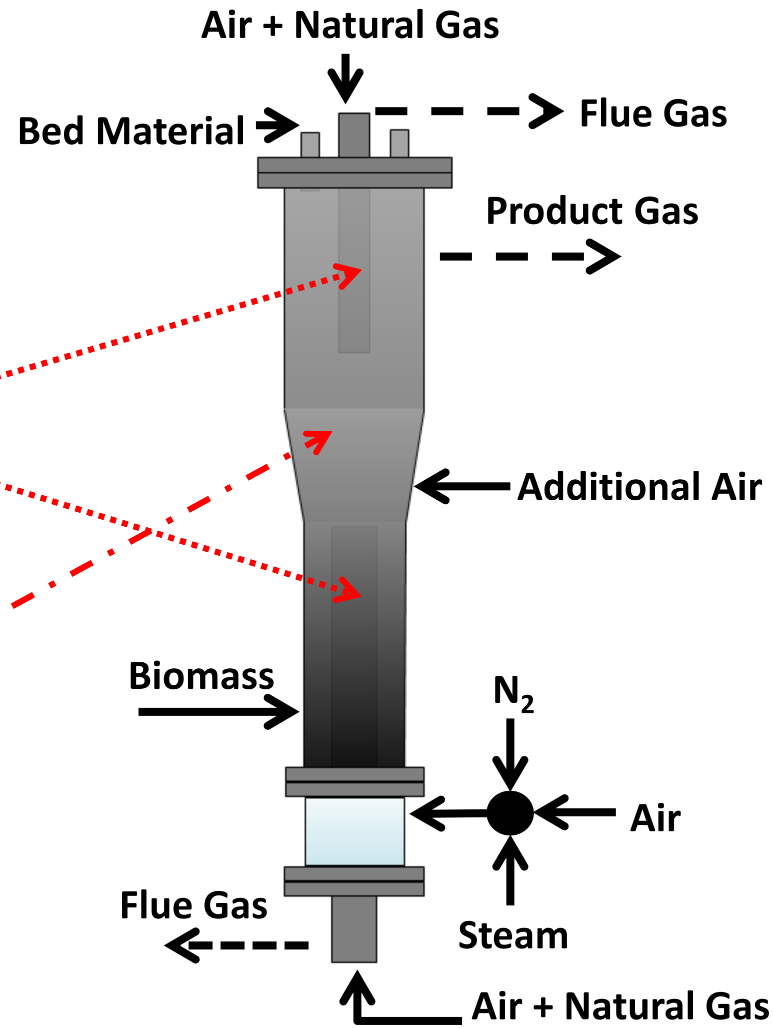


- **Milena**
- **Heat pipe reformer**
- **FICFB**

Project overview: IHBFBSR (TU Delft and Petrogas-Gas Systems, the Netherlands)

Combustion:
Radiant tube burners

Gasification:
Bubbling Fluidized Bed reactor



Research objectives and methodology

- Conduction of gasification experiments in the IHBFSR setup and comparison of the results to the other relevant technologies (allothermal and autothermal).
- Investigation of the effect of different process parameters (λ, STBR), different biomass feedstocks and bed material sizes.
- Modelling and simulation of biomass gasification in the 50kW$_{th}$ IHBFBSR with Aspen Plus™

Materials

- **Biomass feedstocks characterization**

	RB	GB	Miscanthus
Ultimate analysis (d.a.f. basis)			
C	48.11	48.76	47.05
H	6.47	6.06	6.45
O	45.35	44.86	45.91
N	0.06	0.30	0.51
S	0.01	0.01	0.07
Proximate analysis (a.r. basis)			
Moisture	5.57	5.08	6.70
Volatile matter	79.90	75.22	72.77
Fixed carbon	14.07	19.01	16.70
Ash	0.46	0.69	3.83

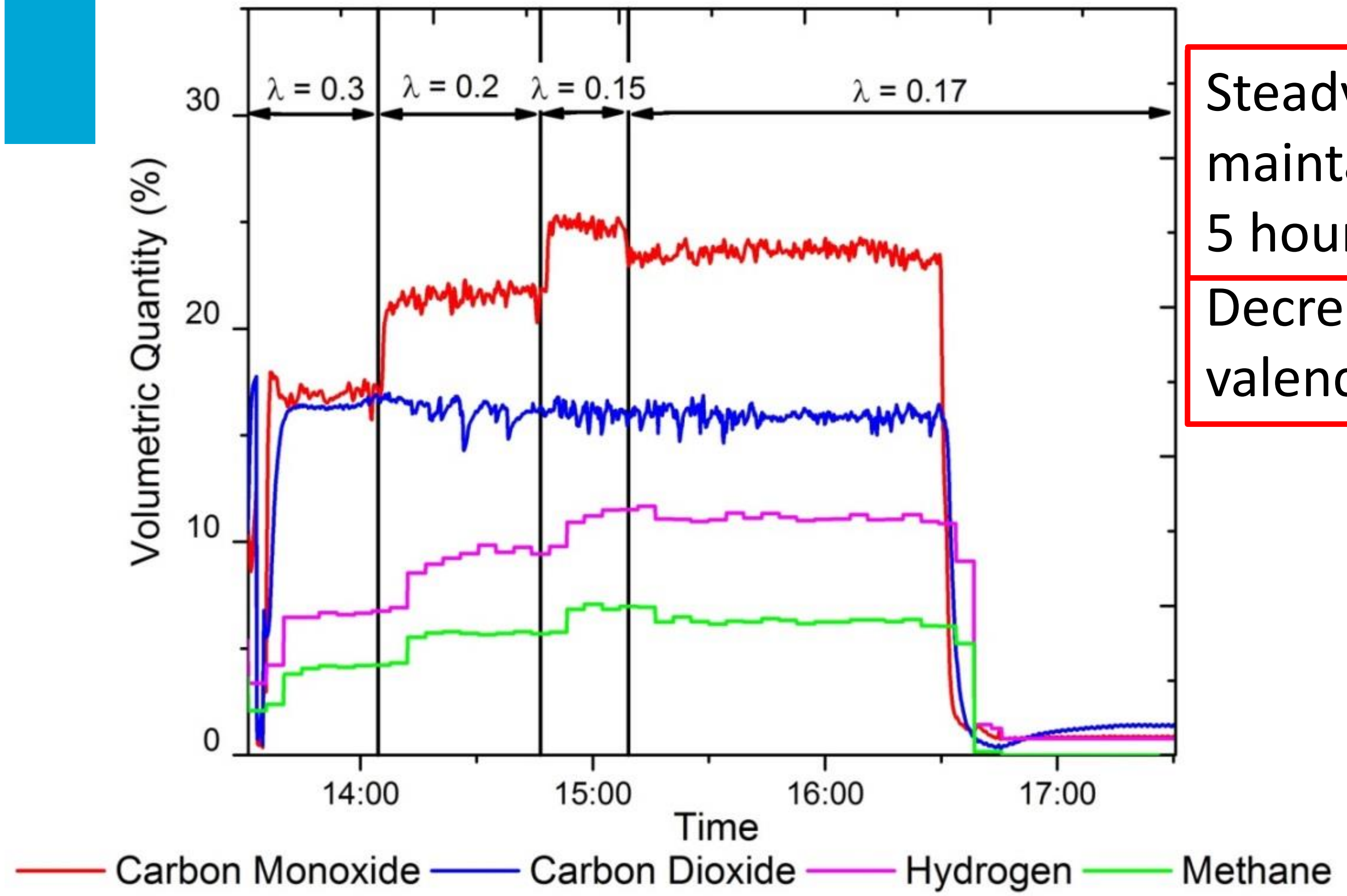
Operating parameters

- Biomass: GB
- Gasification agent: 19 kg/h of air and 4 kg/h nitrogen (purge flow)
- Bed material: 100 kg of Corundum F046 (d≈592 µm)
- Temperature: 840 ˚C

Test operating parameters summary

Parameter	Test 1	Test 2	Test 3	Test 4
Equivalent ratio λ (-)	0.15	0.17	0.2	0.3
Biomass flow rate (kg/h)	23.2	20.5	17.4	11.6

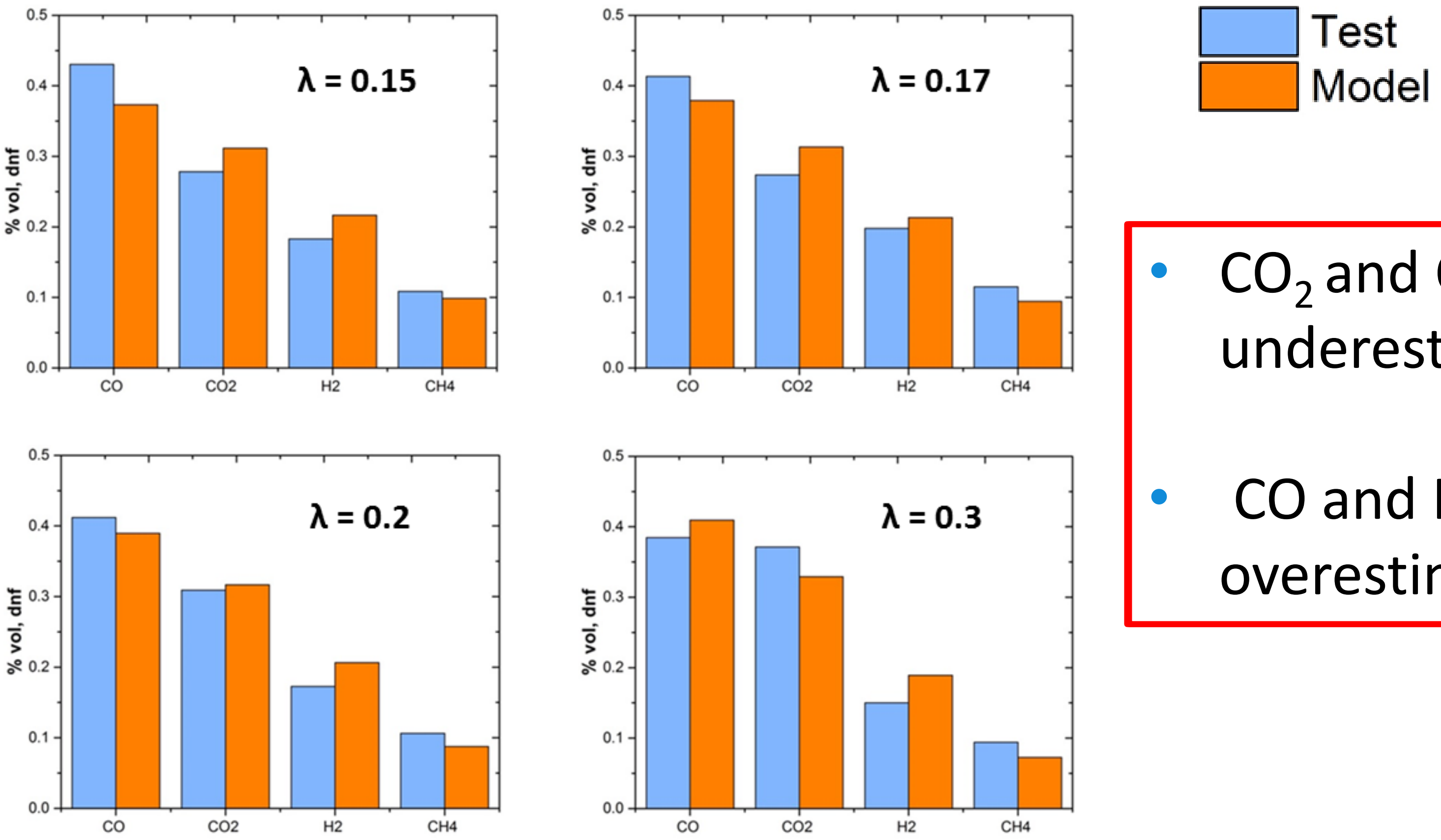
Results and discussion



Steady state (840˚C) maintained for about 5 hours
Decreasing the equi-valence ratio (λ)

Results and discussion

- **Comparison between experimental and model results**



- CO_2 and CH_4 underestimated
- CO and H_2 overestimated

Conclusions

- First tests performed: the reactor can maintain constant temperature in a day test
- Feeding system, radiant tubes burners and control software work according expectations
- The trends of the experimental product composition were as expected
- Good correlation between experimental and model results with a maximum absolute error of roughly 3% for CO

Future work

- **Experimental study**
  - Commissioning of the steam line
  - Gasification campaigns considering different process parameters (λ, STBR), different biomass feedstocks and bed material with different particle sizes
  - Analysis of the liquid samples (tar and water content)

- **Process modelling**
  - Include devolatilization yields expressions as function of temperature for tars and water in the pyrolysis model from experimental results
  - Consider the influence of the particle size distribution
  - Calculation of energy balances and economic analysis
  - Model validation of the various outlet streams and different gasification media

Dank voor het luisteren
Thank you for listening

IEA Bioenergy

Energy Technology Network

Contact Details

Berend Vreugdenhil

berend.vreugdenhil@tno.nl

IEA Bioenergy Website
www.ieabioenergy.com

Contact us:
www.ieabioenergy.com/contact-us/